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TECHNICAL MEMORANDUMS

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No. 419

EXPERIMENTS WITH THREE HORIZONTAL EMPENNAGES

By R. Seiferth

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EXPERIMENTS WITH THREE HORIZONTAL EMPENNAGES.*

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The results of previous experiments with various empennages, including several series performed in the old Göttingen wind tunnel, were published in Volume I of "Technische Berichte."** Since these publications are now difficult to obtain, this communication on some recent systematic experiments with empennage models will doubtless be welcome.***

The main object of the experiments was to determine how the air forces on the whole empennage are affected by varying the size of the elevator without changing the size of the whole empennage. The secondary object was to determine how the magnitude of the air forces acting on the elevator (or the elevator moments) are affected by varying the angle of attack of the whole empennage (α), or of the elevator alone (β). The three empennages, on which the experiments were performed, were of the same size and profile and had the ground plan shown in Fig. 1. Their profile, a symmetrical one of medium thickness,**** is shown in Fig. 3, which also shows the three different elevator

*"Messungen an drei Höhenleitwerken." "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen," Report III, 1927, pp. 102-107.

**Max Munk, "Systematische Versuche an Leitwerkmodellen," pp. 168 ff. and "Untersuchen eines Leitwerks mit verschobener Ruderachse" pp. 223 ff.

***Performed for the "Deutsche Versuchsanstalt für Luftfahrt."

****Profile 409 from Report I of "Ergebnisse."

arrangements. In contrast with the sheet-metal empennages used in the earlier experiments, the models were made, in the now customary manner, of plaster of Paris with a sheet-metal framework.* Their method of suspension is shown in Fig. 2.

Normal three-component measurements were first made on the three empennages, at elevator deflections of 0°, 10° and 20°, for determining the air forces. At $\beta = 0^\circ$, only the empennage No. 1 was thoroughly tested, since all three empennages have the same shape with this position of the elevator. The effect of the gap is negligible, as determined by preliminary tests of empennages 2 and 3.

The results of the first series of experiments are given in Tables I-VII. The areas and chords, on which the coefficients are based, are given at the head of the tables. The leading edge of the stabilizer is the reference axis of the moments. In Figs. 4-6 the values are plotted as polar curves, in order to facilitate their comparison with one another, the measurements being plotted in each instance at the same elevator deflection.** As was to be expected, the lift increases with the elevator deflection (at $\beta = 20^\circ$, the maximum lift is about 50% greater than at the zero position of the elevator), but the drag increases at a much greater rate. At small angles of attack, the relatively small drag of the empennage with $t_R = \frac{1}{2}\, t$

*See Report I, No. III, 7, "Die Herstellung der Modelle."
**The relation $t_R = 0.25\ t$, given in the diagrams, is only approximate. The exact values can be obtained from Fig. 3.

is noticeable, being some of the time less than with $t_R = \frac{3}{8}$ t.

In the second series of experiments measurements were made of the elevator moment at various angles of attack of the stabilizer and deflections of the elevator. For this purpose, a wire ran vertically up from the trailing edge of the elevator to a special balance. The stabilizer was held rigidly at the different angles of attack by suitable bracing, so that only the force P_R, acting on the elevator end at the distance t_R from the elevator axis, was measured (Fig. 10). The real elevator moment is therefore $M_R = P_R\, t_R \cos(\alpha + \beta)$. The coefficient c_R given in Tables VIII-X then becomes

$$c_R = \frac{M_R}{q\, F_R\, t_R} .$$

In Figs. 7-9, the values of c_R are plotted against the angle of attack α and the elevator deflection β, and separately for each empennage. Lastly, the values for all three empennages are assembled in Fig. 11, where c_R is plotted against α for the same elevator deflection β.

Horizontal Empennage No. 1.

Span $b = 100.0$ cm; Total maximum chord $t = 25.2$ cm;

Total area $F = 2325$ cm²; Elevator chord $t_R = 6.5$ cm.

TABLE I.

Elevator deflection $\beta = 0^\circ$

α	$100\ c_a$	$100\ c_w$	$100\ c_m$
-5.9°	-33.5	2.06	-6.7
-2.9	-16.2	1.11	-3.3
0	+ 1.71	0.82	+0.4
+2.9	19.8	1.24	4.1
5.8	37.1	2.15	7.8
8.8	54.5	3.82	11.6
11.7	70.0	6.00	14.7
13.7	79.0	7.79	16.4
14.7	82.1	8.74	17.1
17.7	62.6	19.3	20.2

TABLE II.

Elevator deflection $\beta = 10^\circ$

α	$100\ c_a$	$100\ c_w$	$100\ c_m$
-17.8°	-45.3	16.0	-9.7
-14.7	-60.7	5.56	-6.9
-11.8	-43.0	3.52	-1.9
- 8.9	-25.1	2.13	+2.7
- 6.0	- 7.7	1.45	5.9
- 3.0	+11.3	1.34	10.1
- 0.1	28.4	1.87	14.0
+ 2.8	45.0	3.00	17.0
5.7	60.3	4.69	19.8
8.7	75.5	6.86	22.2
11.6	90.0	9.66	25.1
13.6	99.0	11.8	26.8
15.2	77.3	21.5	28.9

TABLE III.

Elevator deflection $\beta = 20^\circ$

α	$100\ c_a$	$100\ c_w$	$100\ c_m$
-17.9°	-28.9	13.4	-0.3
-14.8	-44.8	5.14	+1.4
-11.9	-25.5	3.59	6.9
- 9.0	- 6.9	2.99	11.4
- 6.0	+ 9.1	3.04	14.7
- 3.1	26.5	3.57	18.3
- 0.2	43.7	4.67	22.1
+ 2.7	61.2	6.28	25.6
5.7	76.4	8.36	28.0
8.6	92.3	10.8	31.2
11.5	107.7	13.7	34.5
13.0	114.7	15.7	35.8
14.6	90.7	26.6	36.7

Horizontal Empennage No. 2.

Span b = 100.2 cm; Total maximum chord t = 25.3 cm;

Total area F = 2326 cm²; Elevator chord t_R = 9.1 cm.

TABLE IV.

Elevator deflection $\beta = 10^\circ$

α	100 c_a	100 c_w	100 c_m
-17.8°	-40.1	14.5	-10.1
-14.8	-51.3	4.57	- 5.2
-11.9	-35.4	2.91	- 1.0
- 8.9	-17.2	1.84	+ 4.5
- 6.0	- 0.5	1.40	8.0
- 3.1	+17.0	1.59	11.5
- 0.1	34.0	2.37	15.3
+ 2.8	49.0	3.71	17.9
5.7	60.3	5.39	19.3
8.7	74.2	7.60	22.1
11.6	89.0	10.3	25.0
14.6	101.9	13.6	27.8
15.7	74.6	23.4	28.2

TABLE V.

Elevator deflection $\beta = 20^\circ$

α	100 c_a	100 c_w	100 c_m
-17.9°	-20.9	11.7	2.4
-14.9	-27.2	4.48	7.6
-11.9	-14.3	4.35	10.6
- 9.0	+ 1.0	4.24	13.3
- 6.1	16.7	4.56	16.4
- 3.1	32.7	5.45	19.8
- 0.2	51.0	7.11	24.0
+ 2.7	64.8	8.57	26.1
5.7	78.6	10.6	28.5
8.6	93.5	13.3	31.7
11.5	107.9	16.5	34.8
12.5	111.6	17.5	35.6
13.5	115.2	18.5	36.0
14.6	90.5	28.2	36.2

Horizontal Empennage No. 3.

Span b = 99.85 cm; Total maximum chord t = 24.97 cm;

Total area F = 2297 cm²; Elevator chord t_R = 12.0 cm.

TABLE VI.

Elevator deflection $\beta = 10^\circ$.

α	100 c_a	100 c_w	100 c_m
-17.8°	-42.2	13.5	-9.4
-14.8	-47.0	4.30	-2.9
-11.9	-30.6	2.62	+0.4
- 8.9	-13.9	1.65	3.8
- 6.0	+ 3.3	1.28	7.6
- 3.1	20.4	1.51	11.2
- 0.2	42.9	2.75	16.2
+ 2.8	56.1	4.31	18.9
5.7	69.2	5.95	21.6
8.7	83.6	9.01	24.4
11.6	93.7	11.9	27.0
14.6	104.4	15.1	29.3
15.5	107.7	15.9	30.2
16.7	82.0	25.4	29.7

TABLE VII.

Elevator deflection $\beta = 20^\circ$

α	100 c_a	100 c_w	100 c_m
-17.9°	-16.3	9.18	2.3
-16.4	-13.6	7.61	4.2
-15.0	- 1.8	2.49	13.6
-12.1	+14.7	2.43	17.3
- 9.1	30.9	3.09	21.1
- 6.2	47.0	4.59	24.7
- 3.3	59.8	7.02	28.0
- 0.3	70.4	9.61	30.0
+ 2.7	75.6	11.7	29.5
5.6	87.8	14.4	32.0
8.6	100.9	17.3	34.7
11.5	112.8	20.2	37.1
14.5	122.0	22.9	38.5
15.7	97.1	32.2	37.9

Horizontal Empennage No. 1.

TABLE VIII.

Elevator area F_R = 527 cm²;
Elevator chord t_R = 6.5 cm.

Angle of attack α	Elevator deflection β	100 c_R
0.2°	-20°	-19.02
0.1	-10	- 9.78
0.0	0	+ 0.45
-0.1	+10	9.00
-0.2	+20	17.75
3.1°	-20°	-17.57
3.0	-10	- 9.86
2.9	0	+ 0.90
2.8	+10	9.28
2.7	+20	17.72
6.0°	-20°	-16.29
6.0	-10	- 7.96
5.8	0	+ 2.01
5.7	+10	9.17
5.7	+20	17.80
9.0°	-20°	-15.23
8.9	-10	- 8.08
8.8	0	+ 1.79
8.7	+10	9.26
8.6	+20	18.31
11.9°	-20°	-13.40
11.8	-10	- 6.18
11.7	0	+ 2.05
11.6	+10	10.90
11.5	+20	18.92
14.8°	-20°	- 9.55
14.7	-10	- 3.04
14.7	0	+ 7.50
14.6	+10	16.64
14.6	+20	24.18
17.9°	-20°	- 7.58
17.8	-10	+ 0.86
17.7	0	10.35
17.7	+10	17.70
17.7	+20	23.80

Horizontal Empennage No. 2.

TABLE IX.

Elevator area F_R = 764 cm²;
Elevator chord t_R = 9.1 cm.

Angle of attack α	Elevator deflection β	100 c_R
0.2°	-20°	-18.96
0.1	-10	- 8.76
0.0	0	+ 0.61
-0.1	+10	8.76
-0.2	+20	18.61
3.1°	-20°	-17.66
3.1	-10	- 7.23
2.9	0	+ 1.10
2.8	+10	9.62
2.7	+20	19.10
6.1°	-20°	-16.00
6.0	-10	- 5.41
5.8	0	+ 1.39
5.7	+10	10.20
5.7	+20	19.40
9.0°	-20°	-14.70
8.9	-10	- 4.60
8.8	0	+ 2.40
8.7	+10	11.50
8.6	+20	20.30
11.9°	-20°	-13.53
11.9	-10	- 4.17
11.7	0	+ 2.64
11.6	+10	11.66
11.5	+20	20.60
14.9°	-20°	-12.78
14.8	-10	- 3.62
14.7	0	+ 7.47
14.6	+10	18.89
14.6	+20	29.00
17.9°	-20°	- 4.54
17.8	-10	+ 4.26
17.7	0	11.70
17.7	+10	18.45
17.6	+20	24.80

Horizontal Empennage No. 3.

TABLE X.

Elevator area $F_R = 1041$ cm²;

Elevator chord $t_R = 12.0$ cm.

Angle of attack α	Elevator deflection β	$100\ c_R$
0.3°	-20°	-20.20
0.2	-10	- 8.63
0.0	0	0
-0.2	+10	+ 8.54
-0.3	+20	+19.88
3.3°	-20°	-19.35
3.1	-10	- 7.11
2.9	0	+ 0.52
2.8	+10	10.93
2.7	+20	20.48
6.2°	-20°	-16.92
6.0	-10	- 5.94
5.8	0	+ 1.12
5.7	+10	12.47
5.6	+20	21.00
9.1°	-20°	-16.00
8.9	-10	- 4.32
8.8	0	+ 2.72
8.7	+10	14.32
8.6	+20	23.20
12.1°	-20°	-16.10
11.9	-10	- 2.92
11.7	0	+ 3.88
11.6	+10	15.40
11.5	+20	24.05
15.0°	-20°	-12.90
14.8	-10	- 2.28
14.7	0	+ 5.97
14.6	+10	19.20
14.5	+20	26.10
17.9°	-20°	- 5.97
17.8	-10	+ 5.55
17.7	0	12.64
17.7	+10	19.58
17.7	+20	26.55

Translation by Dwight M. Miner,
National Advisory Committee for Aeronautics.

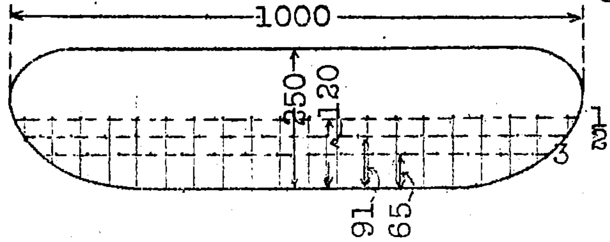


Fig.1

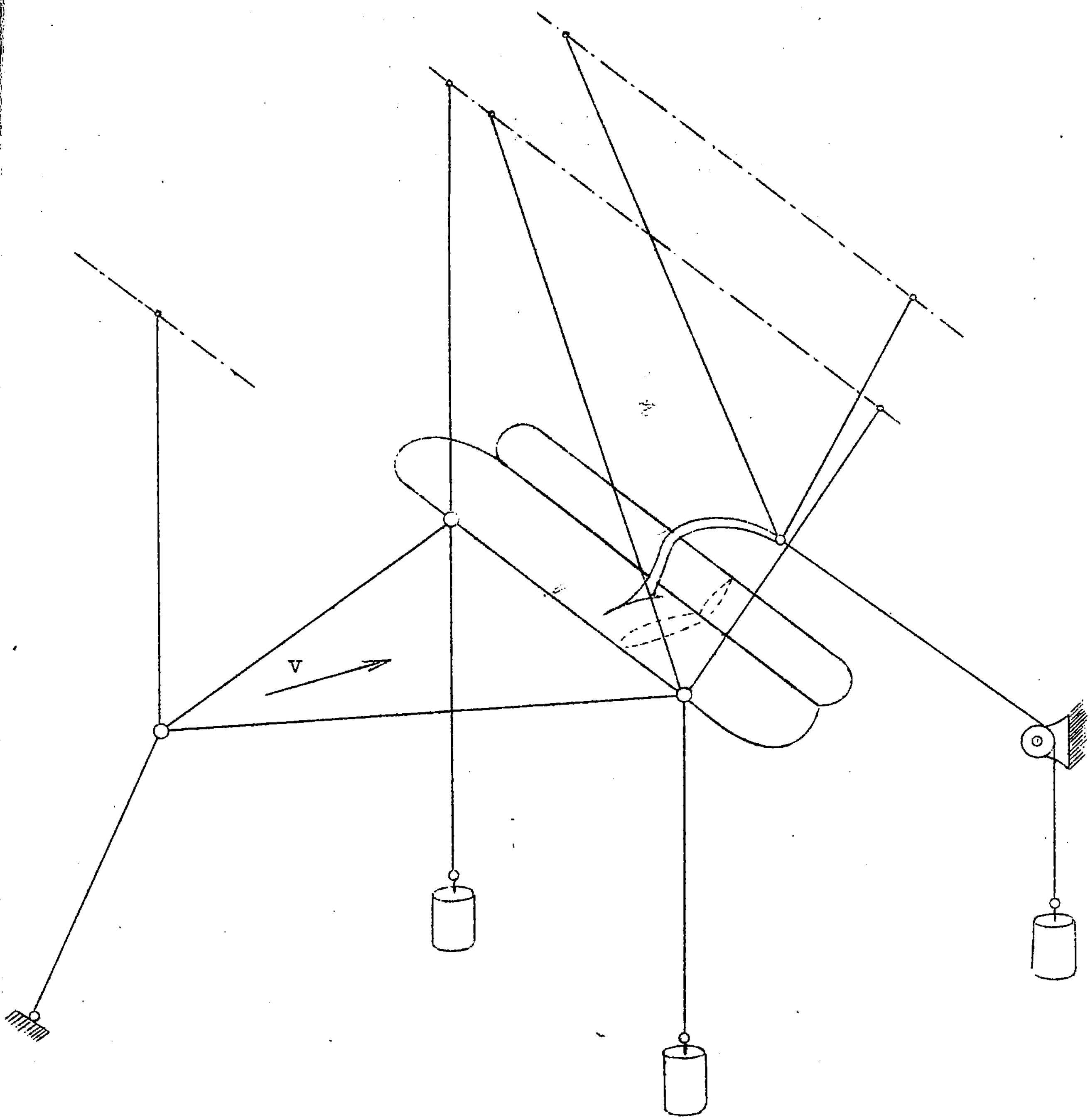


Fig.2

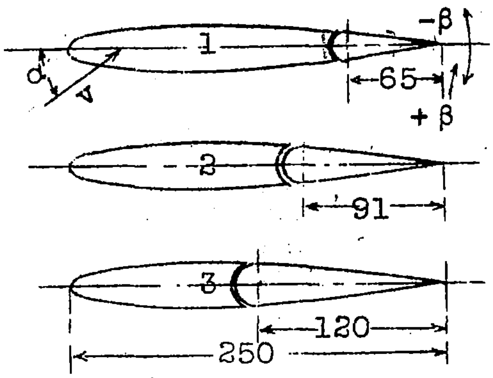


Fig.3

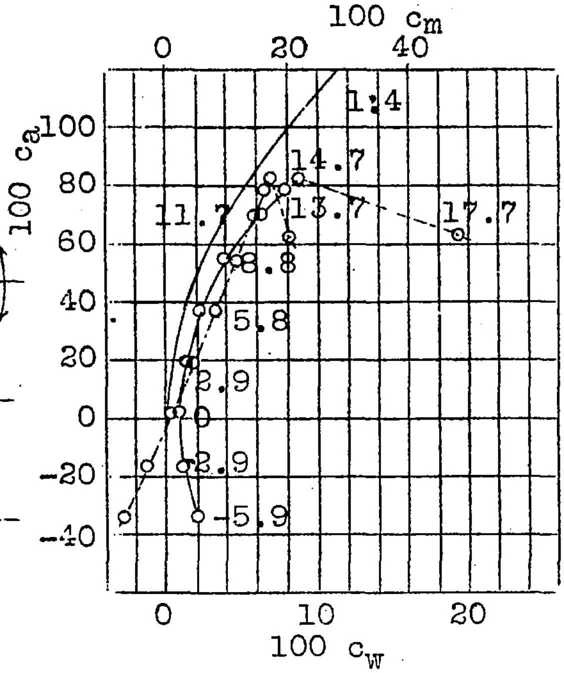


Fig.4 $\beta = 0^o$

○ t_R = 1/4 t
\+ " = 3/8 t
× " = 1/2 t

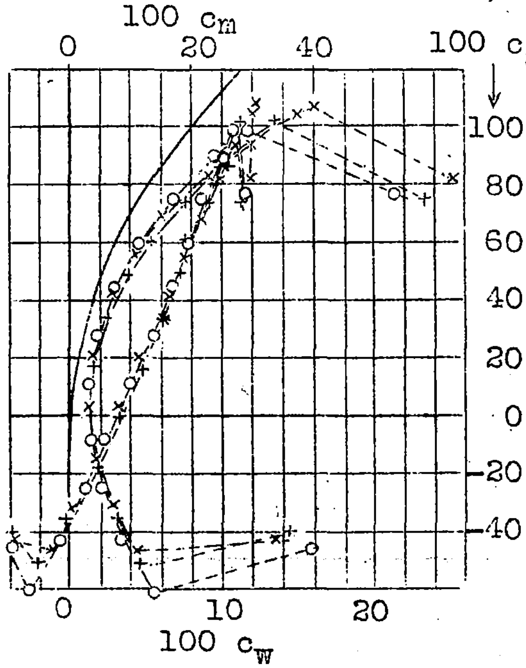


Fig.5 $\beta = 10^o$

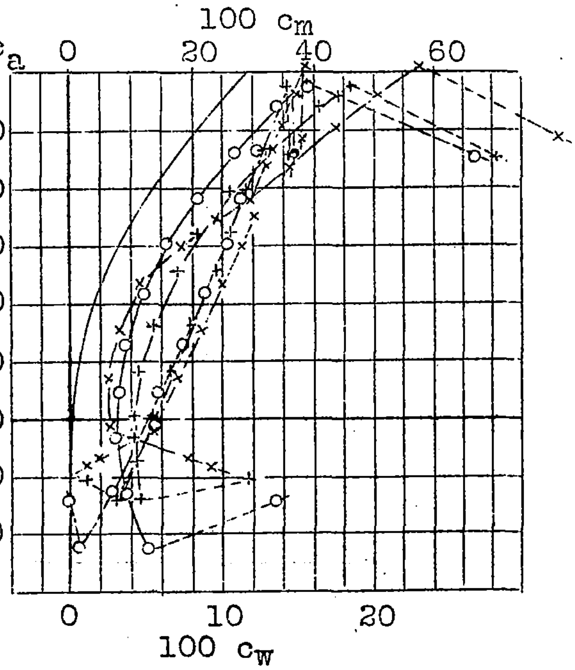


Fig.6 $\beta = 20^o$

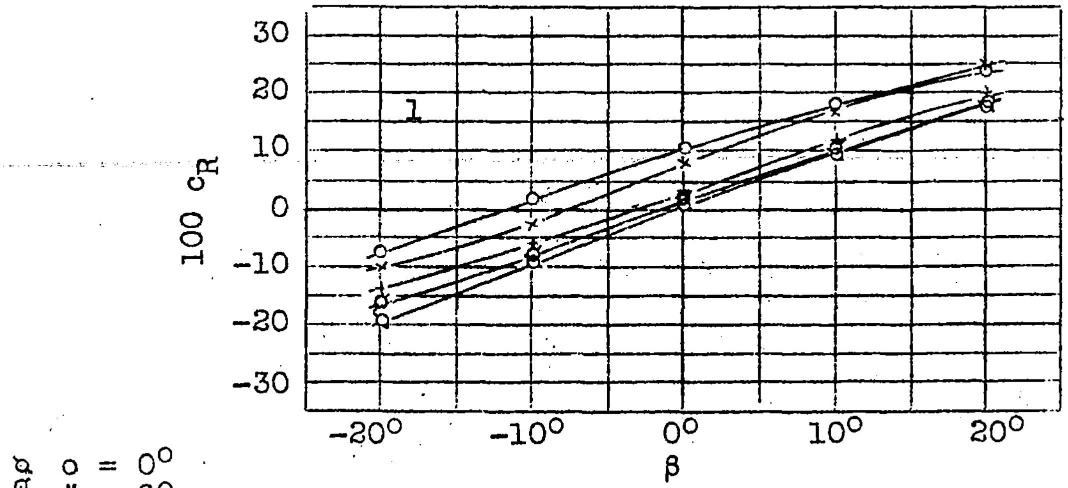


Fig.7

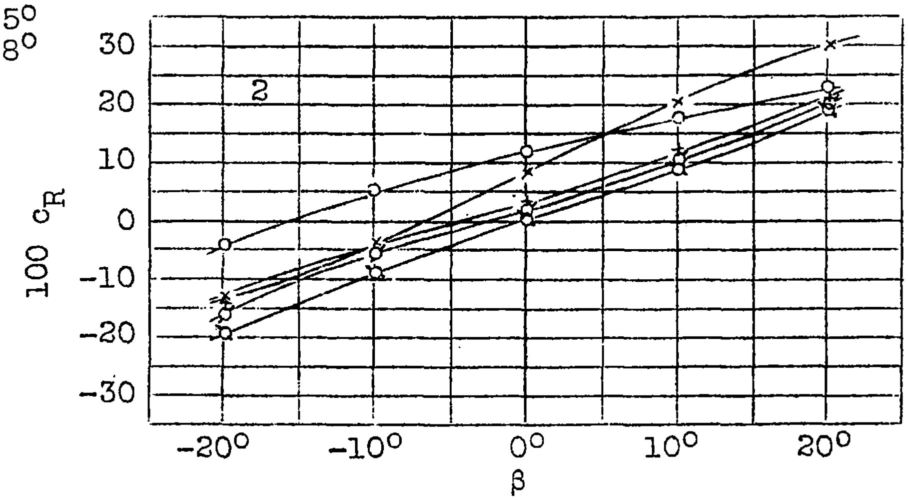


Fig.8

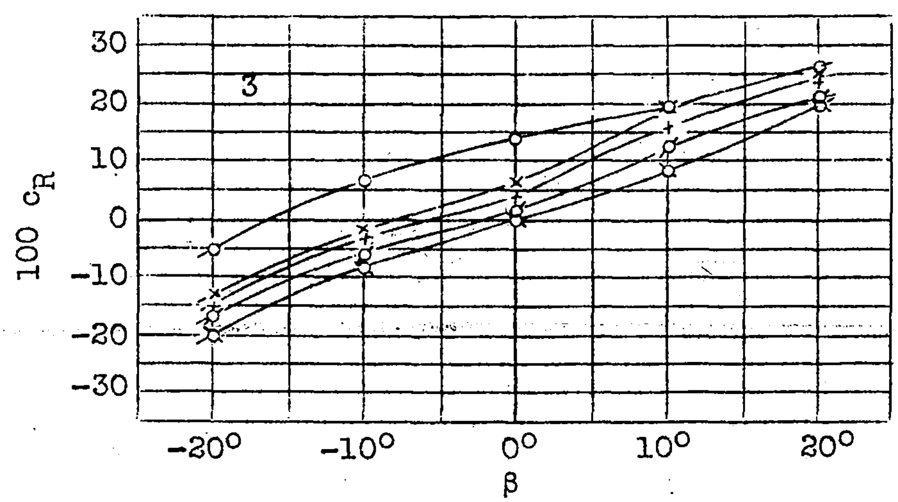


Fig.9

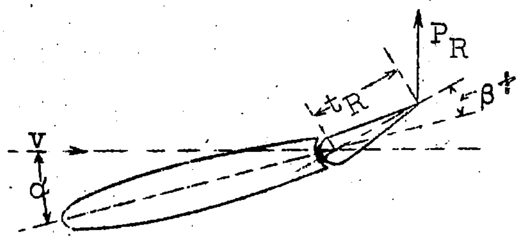
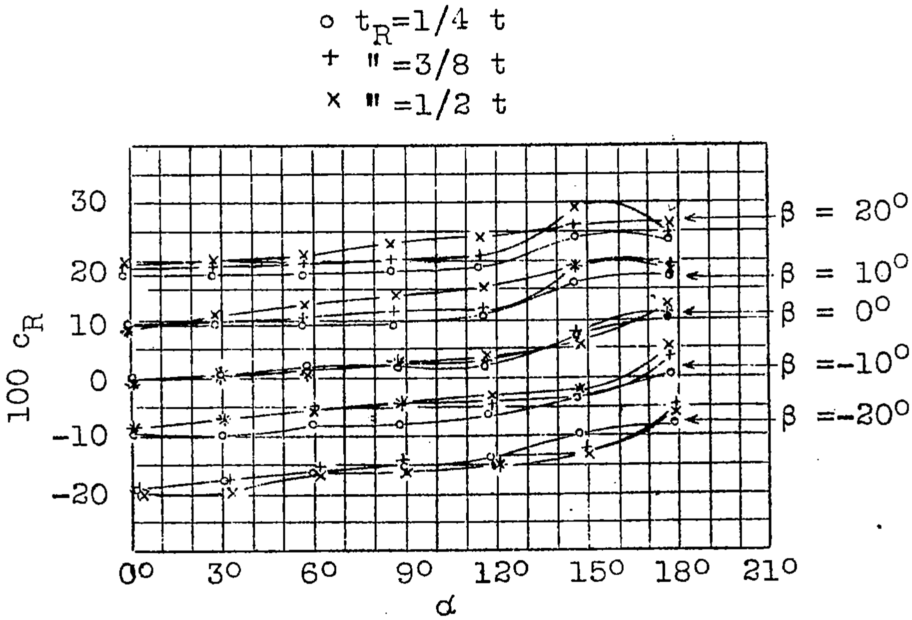

P_R
t_R
β
V
α

Fig.10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+ " =3/8 t
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30
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100 c_R
0° 3° 6° 9° 12° 15° 18° 21°
α
β = 20°
β = 10°
β = 0°
β =-10°
β =-20°

Fig.11